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Transmutation Science Group**

Neutron Leakage from a Lead-Bismuth Target (Diameter = 40 cm, Length = 50 cm)



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Abstract

Initial measurement of neutron leakage from a 20-cm-diameter, proton-irradiated target was conducted in December 2001 at the WNR-2 facility (commonly called the Blue Room) of the Los Alamos Neutron Science Center (LANSCE). This work was in support of the Advanced Accelerator Applications (AAA) Program (now Advanced Fuel Cycle Program). A preliminary report describing that work is available in LA-UR-02-5552. A continuation of the experimental series was undertaken with the irradiation of a 40-cm-diameter target, as well as follow-up measurements on the 20-cm-diameter target. This report describes this series of irradiations that were conducted in July 2002 at the WNR-2 facility.

The first phase of the experiment consisted of irradiating a solid lead-bismuth target (diameter = 40 cm, length = 50 cm) with the 800-MeV proton beam and measuring the neutron emission from the target by two different methods activation foils and time-of-flight (TOF) measurements.

For the activation foil measurements, numerous foil packets were assembled and mounted on the target for a specified irradiation period. The procedure employed was similar to the protocol used in the December 2001 irradiation of the 20-cm-diameter target, and the experience gained was used to optimize the data gathered from the foils. Twenty-three foil packets were then mounted on the target and an irradiation was conducted overnight from July 9 to July 10, 2002. After the irradiation, most of the foils were withdrawn and the gamma activity was counted at the LANSCE facility and at the LANL Isotope and Nuclear Chemistry department, an analytical laboratory at TA-48, to obtain activation levels and to identify peaks of interest for specific reactions. Some preliminary results are reported here.

Upon completion of the foil activation run, TOF measurements were performed using four flight paths (7.5j, 30j, 60j, and 150j) on July 10–12, 2002. The spectra were measured for three different axial locations of the target the focal point of the neutron flight paths at the front face of the target, 20 cm into the target, and 40 cm into the target. Some initial results are included in this report. Three remaining activation foils that had been left on the target were also withdrawn and counted at the end of this irradiation period.

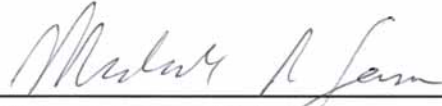
At the termination of this experimental phase, the 40-cm-diameter target was removed from the beamline and the 20-cm-diameter target was put into place. This was done with the intent of taking TOF data using the 60j and 150j flight paths that were not available during the December 2001 irradiation. The target was irradiated on July 12–14, 2002, and neutron spectra were measured at three axial position of the target.



Preliminary results indicate that both techniques for measuring the neutron leakage provide useful and complementary information. The activation foils provide significant quantities of integral reaction data that can be used for spectral unfolding, with errors representative of the uncertainties in the nuclear data. The TOF measurements provide detailed information regarding the neutron spectra in a small solid angle (i.e., double differential data).

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Neutron Leakage from a Lead-Bismuth Target
(Diameter = 40 cm, Length = 50 cm)



Table of Contents

Abstract	iii
Signatures	iv
Additional Authors.....	v
Distribution List	v
List of Figures	ix
List of Tables.....	ix
List of Acronyms.....	x
1. Introduction.....	1
2. Experiment Description.....	3
2.1 Target and Support Equipment	4
2.1.1 Target Fabrication.....	4
2.1.2 Target Support	5
2.1.3 Target Alignment.....	7
2.2 Neutron Time-of-Flight Paths	7
2.3 Activation Foils and Foil Packets.....	8
2.4 Gamma Counting Systems.....	9
3. Experiment Plan and Timeline	15
4. Preliminary Results	17
4.1 Beam Monitoring	17
4.2 Foil Counting	21
4.3 Nuclide Identification	24
4.4 Time-of-Flight Measurements.....	24
4.5 TA-48 Counting	25
5. Summary	26
6. References	28
7. Acknowledgments	29
Appendix A: Count Log.....	30



Neutron Leakage from a Lead-Bismuth Target
(Diameter = 40 cm, Length = 50 cm)



List of Figures

Figure 1. Schematic diagram of WNR Target 2 and the flight path used for neutron measurements.....	3
Figure 2. Schematic diagram of the experimental configuration showing the beam monitoring equipment.	4
Figure 3. Schematic of LBE target on the aluminum support structure.	6
Figure 4. LBE target on the aluminum support structure.....	6
Figure 5. Photograph of exposed radiochromic film. The beam spot is visible as a small blue shadow just left of the ruler.....	7
Figure 6. Assembled foil packet before being wrapped in Al foil.....	9
Figure 7. Exterior view of vertically mounted HPGe (Detector 3) reconfigured from an unshielded, horizontal mount.....	10
Figure 8. HPGe 7 inside of low-background lead-shielded cave.	10
Figure 9. The internals of the shielded cave of Detector 7 showing the sample mounting assembly.....	11
Figure 10. One of the tables fabricated to hold the samples at fixed distances from the detector in Detector 3.....	11
Figure 11. Planned counting schedule.	12
Figure 12. A portion of the Bi gamma spectrum. The center peak at 841.7 keV is the most prominent peak without interferences for Bi-199.	22
Figure 13. The activity of Bi-204 lines as a function of radial position at the 15-cm and 40-cm axial locations.....	22
Figure 14. The ratio of activities for bismuth isotopes normalized to 1 at 15 cm.....	23
Figure 15. Neutron spectrum computed in MCNPX at the 15-cm axial location.	23
Figure 16. Time-of-flight spectra measured with the high-energy detectors for the target position at 0 cm. The data are for 7.5j, 30j, 60j, and 150j.	25

List of Tables

Table 1. Flight Path Collimation and Field-of-View at the Target Location.....	8
Table 2. Characteristics of HPGe Detectors 3 and 7.....	12
Table 3. Source Characteristics for Analytics Source SRS-63752-16.....	13
Table 4. Source Characteristics for Source QCD1998.....	13
Table 6. Computed Distances for Detector-to-Sample Spacing.....	14
Table 7. Determinations of Total Proton Fluence.....	19



List of Acronyms

AAA	Advanced Accelerator Applications
ADC	Analog-to-digital converter
ADTF	Accelerator-Driven Test Facility
AFC	Advanced Fuel Cycle
ANL	Argonne National Laboratory
CCD	Charged-coupled device
FWHM	Full width at half maximum
HPGe	High-Purity Germanium (detectors)
ICT	Integrating current transformer
KeV	Thousand electron volts
LANL	Los Alamos National Laboratory
LANSCE	Los Alamos Neutron Science Center
LBE	Lead-bismuth eutectic
MCNPX	Computer code used in modeling high-energy physics reactions
MeV	Million electron volts
nA	nanoamperes
NIST	National Institute of Standards and Technology
PCGAP	Gamma-ray analysis program
TOF	Time-of-flight
VCR	Video cassette recorder
WNR	Weapons Neutron Research

1. Introduction

Spallation neutron sources create high-energy neutrons whose energies extend up to the incident proton energy. In the design of accelerator-driven waste transmuters, the high-energy neutrons that leak from the spallation target have three practical implications. First, they dominate the shield design because they have long attenuation lengths (18 cm in steel). Second, they lead to the production of source neutrons in the fuel region, which generates a spatially dependent neutron source that influences the power density distribution in the blanket. Third, they dominate the production of H and He atoms in the steel structural elements that reside in the multiplier region near the target. This gas production limits the lifetime of structural materials near the target.

As a means of reducing gas production in structural materials in the multiplier region, a buffer region consisting of high-atomic-mass material may be placed between the target and multiplier. This buffer attenuates high-energy neutrons that leak from the target into the multiplier. Additionally, the configuration of the buffer and the associated beam rastering parameters are variables available to designers of accelerator-driven waste transmuters for adjusting the multiplier power distribution.

MCNPX is the physics code being heavily used in the design process to predict the creation and transport of high-energy particles in accelerator-driven waste transmuter conceptual design studies. Data are necessary to validate that MCNPX is correctly predicting the production and transport of neutrons from the spallation target. This series of experiments will provide benchmark data regarding the magnitude, energy spectrum, and spatial profile of neutrons leaking from the surfaces of a cylindrical spallation target. Lead-bismuth eutectic (LBE) is a prime candidate for target material in current accelerator-driven waste transmuter conceptual designs. Therefore, this series of irradiation experiments focuses on spallation targets and buffers made of LBE. Other spallation target candidate materials could be studied in the future if the AFC Project determines it is a priority.

To evaluate the effectiveness of a buffer in modifying the energy spectrum of neutrons leaking from the spallation target into the buffer or blanket regions, measurements will be performed for two different LBE target radii with a fixed target length exceeding the maximum range of the 800-MeV protons in LBE. The target diameters to be used during the measurement campaign are 20 cm and 40 cm. The target lengths are 50 cm. These values were selected because they are prototypical of current designs for the ADTF. Time-of-flight (TOF) measurements and activation foils are used to perform the neutron measurements. The activation foils are assembled into foil packets and are described in the experiment description below. Four neutron flight paths will be used for the TOF measurements.

This report describes the preliminary results for the target irradiations conducted from July 9—14, 2002. The irradiations were conducted on two solid LBE targets, one with a diameter of 40 cm and the other with a diameter of 20 cm. The length of both targets was 50 cm. This experiment is a continuation of an irradiation conducted in December 2001 [1].



For the activation foil measurements, 23 foil packets were mounted on the 40-cm target and an irradiation was conducted July 9—10, 2002. Most of the foils were then removed and the gamma activity counted at the Los Alamos Neutron Science Center (LANSCE) facility and at the LANL Isotope and Nuclear Chemistry department, an analytical laboratory at TA-48.

Upon completion of the foil activation runs, TOF measurements were performed on both the 20-cm and 40-cm targets using four flight paths (7.5_i, 30_i, 60_i, and 150_i) from July 10—14, 2002. The spectra were measured for three different locations of the target the focal point of the neutron flight paths at the front face of the target, 20 cm into the target, and 40 cm into the target. Initial results are included in this report.

The goals of the initial target irradiation experiment were to:

1. provide further experimental data for the effect of larger radii targets on neutron spectrum from lead-bismuth targets,
2. provide experimental data of benchmark quality to be used for validation of MCNPX,
3. provide experimenters with practical experience for conducting these types of measurements and data analysis activities, and
4. further develop methods and improve techniques for spectral unfolding using integral reaction data from activation foils.

Additional system parameters can be studied as part of continuing experiments. There is interest in studying different buffer materials, target materials, coolant materials, and coupled target-buffer geometries. In addition, follow-on measurements of other targets could be conducted based on analysis of the data from the initial measurement series.

2. Experiment Description

The experiment was carried out in the Target 2 area at the Weapons Neutron Research (WNR) facility at LANSCE. Target 2 is a shielded room approximately 12 meters in diameter with a series of flight paths radiating from the center of the room, as shown in Figure 1. Proton beams up to 100 nA can be accommodated. Neutrons leaking from the target could be observed through four flight paths at angles of 7.5°, 30°, 60°, and 150° with respect to the incident proton beam.

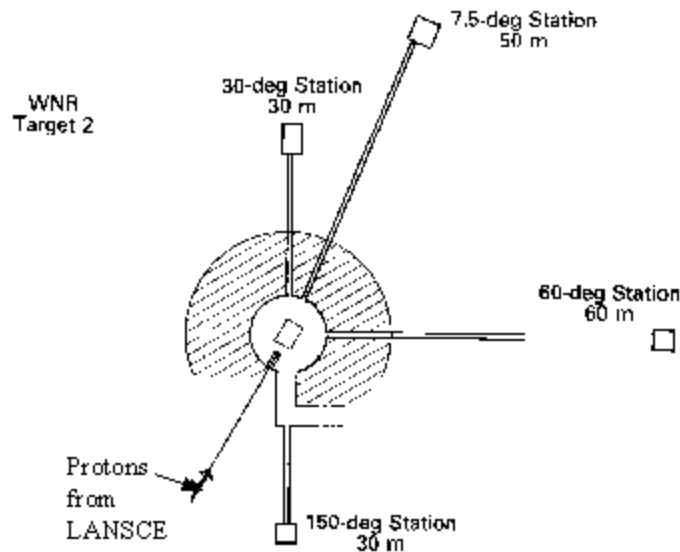


Figure 1. Schematic diagram of WNR Target 2 and the flight path used for neutron measurements.

A schematic diagram of the experimental configuration is shown in Figure 2. Most of the experimental equipment used in this irradiation was described in the previous report [1]. Subsystems, equipment, and procedures that differ from the previous irradiation will be called out in this report.

The LANSCE accelerator provided the proton beam, which exited the beamline vacuum through a thin stainless steel window, traveled about 2 meters through air, and then was incident on the target. A primary requirement for the measurement of proton interactions is the determination of the parameters of the incident beam. These parameters include the total integrated beam striking the target assembly in each irradiation, the position of the beam on the target, and the beam intensity profile. The beam monitor system used was essentially identical to the configuration of the December irradiation and is shown schematically in Figure 2. One significant exception involved the use of radiochromic film

to provide better alignment of the axis of the target with the proton beam. This alignment procedure is described in detail in Section 2.1.3 Target Alignment.

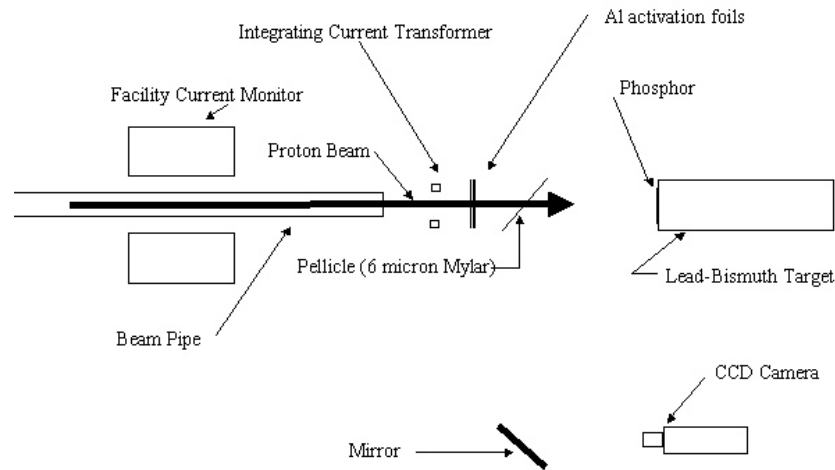


Figure 2. Schematic diagram of the experimental configuration showing the beam monitoring equipment.

2.1 Target and Support Equipment

The dimensions for the cylindrical target for this phase of the neutron leakage experiment were 40-cm diameter and 50-cm length. The target was made of solid LBE, and details of its fabrication are given in this section. The 20-cm target and supports employed in the second phase of the irradiation are described in detail in Reference 1.

2.1.1 Target Fabrication

The required dimensions for a cylindrical target for the neutron leakage experiment were 20-cm radius and 50-cm length. The target was made of solid LBE. Lead-bismuth eutectic is an alloy with 44.5% lead and 55.5% bismuth. For this target the metal was purchased from Ney Smelting and Refining Co., Brooklyn, NY. The lead-bismuth purity as requested was 99.99%.

The target was made by casting lead-bismuth in a cylindrical mold. A steel pipe with a 16-inch diameter was machined to ensure a constant inside diameter and a smooth finish. A flat plate was welded to the end of the pipe to serve as the mold bottom. Tape heaters were used to heat the mold, and ingots of lead-bismuth were melted inside until the level of the liquid metal reached a height of about 50 cm. The mold was chilled slowly from the bottom up by shutting off heaters and removing insulation from the bottom up. Cooling the mold in this fashion provided for the smallest chance of voids forming inside the final solid.

After the mold and the target were completely cooled, a machinist cut the mold wall axially in two places to remove it. The mold readily came off the target. Since the ends of the cylinder as cast were flat and the length was about 49 cm, the ends were not machined.

The final target dimensions indicated the back surface was angled slightly, probably from the target cooling at a slight angle. Length measurements taken at 90° intervals were 49.1, 48.8, 48.6, and 49.0 cm. The average length was 48.875 cm. The target circumference was measured at three axial locations to be 127 cm, giving a diameter of about 40.43 cm. The target and cradle were weighed together at 1496 lbs (680 kg). The pallet weighed 27 lbs (12.27 kg), giving a final weight of the target alone as 1470 lbs (668.2 kg). The estimated density from these measurements is 10.63 g/cm³. The nominal density of Pb-Bi at room temperature is 10.626 g/cm³, indicating the target was fully dense and lacked significant interior voids. Some surface irregularities were observed on the sides and top of the target in the form of very small holes. These irregularities were considered negligible for the purposes of neutron leakage measurements.

2.1.2 Target Support

The cylindrical lead-bismuth target had to be supported and aligned axially with the proton beam. For that purpose a support structure was built. It was constructed of 3-inch aluminum C-channel. The target was placed horizontally between the aluminum legs. A drawing of the target support is shown in Figure 3. Four aluminum legs 30-cm long were welded to the corners of the C-channel's wider side to hold the target away from the main support table during the experiment. A 0.5-inch-thick aluminum plate was welded at the bottom for mounting and rigidity. Four unidirectional caster wheels were mounted at the corners beneath the bottom to provide additional support for the target when it is mounted on the positioning table.

A remotely actuated positioning table was used to move the target axially during the experiment. Manufactured by H2W Technologies, Valencia, CA, the table was sized to carry a 1500 lb load over 20 inches (50.8 cm) at a speed of less than 0.1 inch/sec with a minimum resolution of 0.01 inch (0.254 mm). The bottom plate of the target support stand was bolted to the traveling stage of the positioning table. A programmable remote controller directed the table motor. The whole assembly was bolted to a heavy-duty lift table that allowed for vertical position adjustment inside the Blue Room.

A drawing of the target with support structure is shown in Figure 3. A photograph of the target and support is shown in Figure 4.

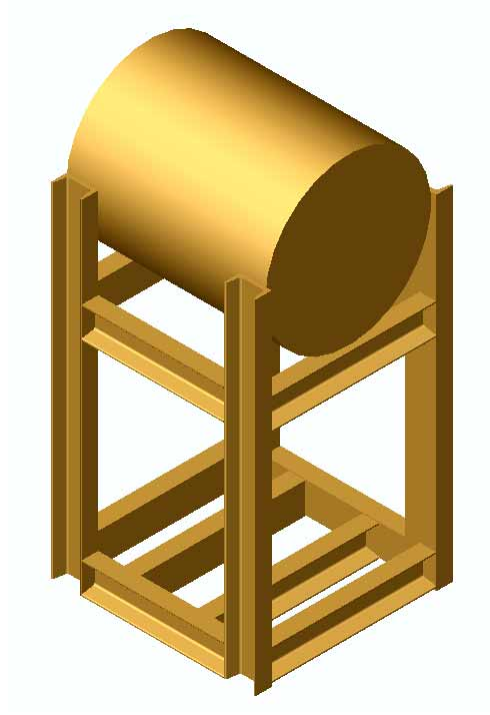


Figure 3. Schematic of LBE target on the aluminum support structure.



Figure 4. LBE target on the aluminum support structure.

2.1.3 Target Alignment

In the July 2002 target irradiations, a procedure was employed to align the targets precisely with the proton beam. This procedure involved radiochromic film affixed to the target stand beneath the target itself. Sheets of film were put in both the front and back planes of the stand. The target was raised above the beam so the radiochromic film was in the proton beam path. A small amount of current was passed through the film (~2-minutes of beam at an average current of ~25 nA), exposing the area where the beam traversed.

Laser pointers were then aimed the position where the proton beam passed through the film, the target was lowered back into position, and the center of the front and back faces were positioned to coincide with the recorded position of the proton beam based on the film exposure. This technique ensured a very close match between the proton beam and the center axis of the target. Figure 5 shows the exposed beam spot being measured prior to moving the target down.

This procedure was performed for both the 40-cm and 20-cm targets before irradiation.

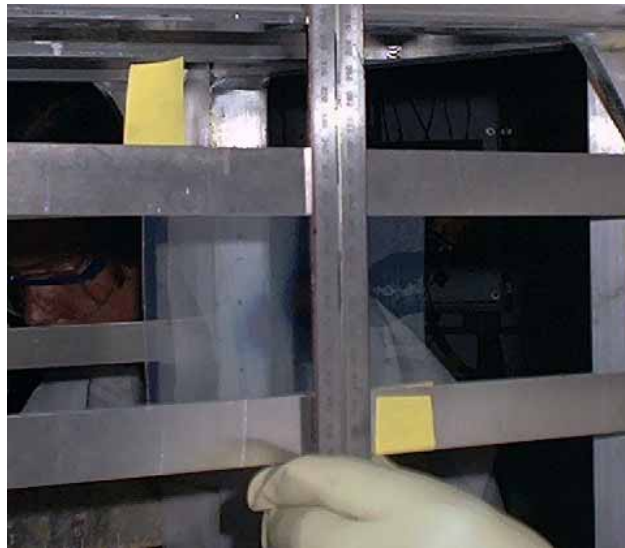


Figure 5. Photograph of exposed radiochromic film. The beam spot is visible as a small blue shadow just left of the ruler.

2.2 Neutron Time-of-Flight Paths

The four beamlines used for the TOF measurements are located at 7.5°, 30°, 60°, and 150° from the proton beam (see Figure 1). A description of the equipment used in the 7.5° and 30° beamlines was given in the previous experimental report [1]. The current experiment added the 60° and 150° beamlines to sample the larger angles of scattering from the target. In all beamlines, calibrated plastic scintillators [2—9] were used to measure neutron TOF spectra for the higher neutron energies. ⁶Li-loaded glass scintillation counters [9] were also used in separate data collection runs and produced

data on low-energy neutron leakage. The flight-path collimation used to define the field-of-view at the target position for these detectors is summarized in Table 1. A thorough description of the beamlines and collimation is provided in References 2—8.

Table 1. Flight Path Collimation and Field-of-View at the Target Location

	7.5 _i Flight Path	30 _i Flight Path	60 _i Flight Path	150 _i Flight Path
Field of View Collimator Diameter (in.)	4.00	4.00	4.00	4.00
Distance from Origin (in.)	168	155	154	198
Distance to Detector (in.)	2013.6	1175.1	2339.3	1240.5
Field of View at Origin (in.)	4.36	4.61	4.28	4.76
Second Collimator Diameter (in.)	3.52	3.75	3.79	
Distance from Origin (in.)	482	234	234	
Field of View at Origin (in.)	4.63	4.68	4.21	
Minimum Field of View (in.)	4.36	4.61	4.21	4.76

2.3 Activation Foils and Foil Packets

The activation foils used in the July 2002 irradiation were selected using the experience of the previous irradiation. The foil packets consisted of several foil materials packaged together for simultaneous irradiation. The materials used for the foil packets were Bi, In, Co, Ni, Cu, Fe, Al, Au, and Tb. Two additional foil packets of Au and Cd-covered gold were also used in the irradiation.

The foils were cut from rolled sheet material and were approximately 1 cm square and 0.25 mm thick. Each foil was weighed and marked with an identification number before being placed into a packet, as shown in Figure 6. The foils were weighed on a Mettler H80 balance scale that was calibrated before use. Twenty-five foil packets were made to handle the various irradiations. Due to a shortage of material, only the stacks labeled 15° through 23 contained Tb foils.

The foils were mounted along the top of the target at 0, 5, 10, 15, 20, 30, 40, and 50 cm from the front face of the target. Also, two rings of foils were mounted at 45_i intervals around the circumference of the target at the 15- and 40-cm axial locations.

Additionally, two foils stacks consisting of Au and Cd-covered Au were exposed to neutron fluxes from the irradiated 40-cm target in a separate phase of the experiment to gauge the level of thermal neutrons from the target.



Figure 6. Assembled foil packet before being wrapped in Al foil.

2.4 Gamma Counting Systems

As in the previous experiment, the foils were counted at both the counting laboratory at TA-48 and at a local counting station in the staging area at the LANSCE facility. The two detectors employed at the LANSCE counting facility were Detectors 3 and 7. For this experiment, the previously unshielded detector (Detector 3) was changed to a vertical mount and was placed inside a lead-shielded cave, with the interior of the cave lined with copper (Figure 7). The configuration of Detector 7 remained unchanged (Figure 8). The samples were mounted on aluminum cards that were prepositioned to center the sample on the detector. By using an inside caliper, sample-to-detector distance could be measured within an accuracy of 0.2 mm. Detector 7 used a mounting fixture (Figure 9), which allowed for easy mounting of samples at fixed reproducible distances. For Detector 3, tables of 5 cm and 10 cm heights were fabricated to hold the samples at fixed distances from the detector (Figure 10). Samples were placed at accurately measured distances of 5.0 cm or 10.0 cm, depending on the level of activity of the sample. The specifications of the detectors are given in Table 2. The measured peak widths (FWHM), typically 2.15 keV, were broader than the manufacturer's specifications in Table 2.



Figure 7. Exterior view of vertically mounted HPGe (Detector 3) reconfigured from an unshielded, horizontal mount.



Figure 8. HPGe 7 inside of low-background lead-shielded cave.



Figure 9. The internals of the shielded cave of Detector 7 showing the sample mounting assembly.



Figure 10. One of the tables fabricated to hold the samples at fixed distances from the detector in Detector 3.

Table 2. Characteristics of HPGe Detectors 3 and 7

Detector Number	Model Number	Crystal Diameter	Crystal Length	Window	FWHM @ 1.33 MeV
3	GEM-40190-P	64.3 mm	59.9 mm	1.0 mm Al	1.79 keV
7	GEM-40190-P	66.5 mm	64.0 mm	1.0 mm Al	1.79 keV

Considerable experience was gained in the December experiment concerning the particular isotopes that were detectable and useful in each foil material. Based on this information, a schedule was created that specified an approximate order for the foil counting. This schedule is shown in Figure 11. The schedule specified the foil material and locations to be counted first, and the approximate length of time for counting and the accumulated time for each group of counts. In practice, minor alterations were made to the schedule based on the observed data. For example, the In foils were only counted for 30 minute intervals because sufficient data could be gathered on the important isotopes with a shorter counting time.

The Bi, Tb, and In foils were a higher priority for the early counting, with Au, Al, Fe, Cu, Co, and Ni foils held for counting later. The counting times also increased as the samples decayed to lower levels of activity.

40 cm Target activation foil counting plan			time/count (h)	elapsed time	Total elapsed time
foils	number	locations			
Bi	6	rear,40,20,0,10,15	0.75	2.25	2.25
Bi	6	40-(90,180,270), 10-(90,180,270)	0.75	2.25	4.5
In	6	rear,40,20,0,10,15	0.75	2.25	6.75
Tb	5	40,20,0,10,15	0.75	1.875	8.625
In	14	remaining	0.75	5.25	13.875
Ship all foils except Au to TA-48 (148?)			Count all foils 90 min (222 hours total) then again for 5 hours (30 days)		
Au	20	all	2	20	33.875 Terminate before next set is pulled from target
Get remaining three foil packets					
Bi	3	50,30,5	1	1.5	1.5
Tb	3	50,30,5	1	1.5	3
In	3	50,30,5	1	1.5	4.5
Au	3	50,30,5	1	1.5	6
Al	3	50,30,5	1.5	2.25	8.25
Fe, Ni, Cu, Co	12	50,30,5	2	12	20.25
Remaining foils at staging Area (3*9+20=47)					
Recount again starting with Bi for 4 hours each?			~1wk		

Figure 11. Planned counting schedule.

Details of the foil counting, isotope identifications, and results are in Section 4.2.

Standards were used to establish the full-energy gamma-ray peak counting efficiencies for each detector and counting distance used in the experiment. These standard sources provide numerous gamma energies that cover the energy range from 88 to 1836 keV. The energy dependence of the efficiency for each detector was established by spectra taken with the mixed standard (SRS-63752-16), with characteristics given in Table 3.

Using the automated efficiency function generator in *PCGAP*, efficiency files were made for each detector at 5 cm and 10 cm source-to-detector distances. The efficiency files 50° and 51 for Detector 3 and 60, 61 and 62 for Detector 7 were created from spectra



taken with SRS-63752-16, and these files were used for analyzing the irradiated foil spectra.

A second calibration standard (Amersham Radiological Source QCD1 number 2582QB manufactured in 1998) was used for the routine calibration checks. Its characteristics are listed in Table 4. Using the efficiency files obtained with SRS-63752-16, the gamma ray counting rates of the QCD1998 source agree with known rates of Cs¹³⁷ and Co⁶⁰ in Table 4 to within 1% for Detector 3 and 2% for Detector 7.

Table 3. Source Characteristics for Analytics Source SRS-63752-16

Nuclide	Energy (keV)	Emission Rate on 4/1/02 (Gammas/sec)	Total Uncertainty (%)	Half-life (days)
Cd-109	88.03	3132	5.0	462.6
Co-57	122.1	1766	4.2	271.79
Ce-139	165.9	2346	4.4	137.6
Hg-203	279.2	4910	4.5	46.61
Sn-113	391.7	3316	4.4	115.1
Cs-137	661.7	2321	4.6	10983.0
Y-88	898	8439	4.3	106.65
Co-60	1173	3956	4.4	1925.2
Co-60	1333	3996	4.3	1925.2
Y-88	1836	8834	4.2	106.6

Table 4. Source Characteristics for Source QCD1998 (Amersham Source Number 2582QB)

Nuclide	Energy (keV)	Emission Rate on 2/1/98 (Gammas/sec)	Standard Deviation (%)	Half-life (days)
Cd-109	88.03	621	2.6	461.4
Co-57	122.1	569	2.2	271.79
Ce-139	165.9	680	4.9	137.64
Hg-203	279.2	1918	2.5	46.612
Sn-113	391.7	2046	5.3	115.09
Sr-85	514	3777	2.4	64.84
Cs-137	661.7	2341	2.5	10983.0
Y-88	898	6059	3.2	106.65
Co-60	1173	3807	0.9	1925.2
Co-60	1333	3811	0.8	1925.2
Y-88	1836	6404	3.2	106.65

Both sources are NIST-traceable.

Because the actual distances between the detector face and the calibration sources differ slightly from the nominal values of 5 cm and 10 cm, corrections were made assuming a simple model of the detector. The effective center of the detector is found by comparing the efficiency of the detector at two or more distances and finding the distance to the effective center so that a $1/r^2$ dependence is obtained where r is the

distance between the point source and the effective center of the detector. The energy dependence of the distances to the effective center is given in Table 5.

Activities are obtained by the equation, $A = \frac{\gamma / s}{BR\epsilon}$, where the efficiency is $\epsilon = \frac{a}{(d + d_{ec})^2}$,

a is a constant, d is the source-to-detector distance, and d_{ec} is the distance to the effective center of the detector in Table 5.

Table 5. Computed Distances for Detector-to-Sample Spacing

Energy (keV)	Distance from the Detector Face to the Effective Center of Detector 3 (cm)	Distance from the Detector Face to the Effective Center of Detector 7 (cm)
88	2.33	2.09
122.1	2.66	2.32
165.9	2.43	2.40
279.2	2.97	2.77
391.7	2.97	2.90
514	3.08	3.10
661.7	3.21	3.21
898	3.47	3.16
1173	3.65	3.60
1333	3.47	3.46
1836	3.78	3.51

An efficiency file (number 107) was also created with *PCGAP* for the TA-48 detector (number 55) based on efficiency data supplied with the counts to enable the data files from the counting done at TA-48 to be analyzed in the *PCGAP* package.



3. Experiment Plan and Timeline

The experiment was performed in accordance with the experiment plan at the LANSCE Target 2 (Blue Room) facility. The details regarding the July irradiations in the Target 2 area are described here in timeline format as recorded in the logbooks. The irradiation was begun on July 9, and irradiation activities continued through July 14. The counting activities and data analysis continued for several weeks afterwards. Results of the foil activations and TOF measurements are included in Section 4. A detailed description of proton-beam monitoring activities is also included.

July 8, 2002

1100-1230 Pre-job briefing conducted, approvals to operate received, RWP review, and other administrative matters

July 9, 2002

0900-1200 Target placed on the stand in the Blue Room
1900-2000 Beam delivered to beamstop for tuning (target was not in position)
2000-2100 Beam aligned with radiochromic film
2130-2230 Foil packets mounted on target
2240-1100 50 nA beam delivered onto Pb-Bi target

July 10 2002

1130-1215 Most foils from target retrieved, foils transported to Staging Area
1215-1600 Set-up, debug TOF system
1600-1828 High-energy TOF measurement at target position of 0 cm.
1828-2035 High-energy TOF measurement at target position of 20 cm.
2035-2235 High-energy TOF measurement at target position of 40 cm.
2235-0030 Detectors switched for low-energy measurements

July 11, 2002

0030-0857 Low-energy TOF measurement at target position of 0 cm.
0857-1727 Low-energy TOF measurement at target position of 20 cm.
1727-1845 Remaining three foils retrieved from target
1845-0315 Low-energy TOF measurement at target position of 40 cm.

July 12, 2002

0315 Beam down for repair of cooling to Target 4
1000-1400 40-cm target removed and placed in the basement of the Blue Room
1400-1800 20-cm target put into place for TOF measurements
1800-2200 20-cm target aligned to proton beam
2200-0052 Low-energy TOF measurement at target position of —1* cm.

* Target position inadvertently shifted 1 cm downstream.



July 13, 2002

0052-1020	Low-energy TOF measurement at target position of 19 cm.
1020-1348	Additional low-energy measurements at —1 cm.
1348-1430	Detectors switched for high-energy measurements.
1430-1600	High-energy measurements at target position of —1 cm.
1600-1726	High-energy measurements at target position of 19 cm.
1726-1900	High-energy measurements at target position of 39 cm.
1900-2030	Detectors switched for low-energy measurements.
2030-0700	Low-energy measurements at target position of 39 cm.

July 14, 2002

1000-1200	20-cm target removed and placed in storage
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July 16, 2002

Shipped most activation foils to TA-48

Foil counting began as soon as the foils were sent to the Staging Area. A copy of the foil counting log is provided in Appendix A.

4. Preliminary Results

4.1 Beam Monitoring

The LANSCE accelerator provided the proton beam. The proton beam exited the beamline vacuum through a thin stainless steel window, traveled about 2 meters through air, and then was incident on the target. A primary requirement for the measurement of proton interactions is the determination of the parameters of the incident beam. These parameters include the total integrated beam striking the target assembly in each irradiation, the position of the beam on the target, and the beam intensity profile. The beam monitor system is shown schematically in Figure 2.

The proton beam monitoring employed was almost identical to the system used in the previous irradiation. It is summarized here.

The system to image the proton beam spot on the front face of the target is shown in Figure 2 and consisted of a Cr-doped aluminum oxide phosphor indexed and accurately centered on the target. A thin, aluminized Mylar pellicle reflected the light from this phosphor into a lens system that relayed the image to a mirror and then into a shielded camera system consisting of a gated image intensifier and a CCD video camera. This system permitted both real-time observation of the beam size and position and also recording of the beam intensity profiles during the course of the irradiation. The image was relayed to the LANSCE accelerator control room, which permitted the operators to quickly correct any diffuse or dislocated beam spots. A video cassette recorder (VCR) recorded the beam spot over the course of the irradiation. However, an error in the VCR operation meant that only the first 2.5 hours and last 3.5 hours of the proton beam spot were recorded for the 40-cm target out of a total irradiation time of 12.3 hours. A review of the beamspot data concluded that the beam was slightly high on the target between 3° and 7 mm but averaging around 4–5 mm.

The incident beam current was monitored in the LANSCE Central Control Room using a standard LANSCE current monitor [10] located in the proton beamline about three meters upstream from the target. A digital reading from this monitor was recorded at 10-second intervals over the course of each irradiation, and the file of current values so generated was used to document the time-dependence of the current and, from its integral, to determine the total number of protons incident on the sample for a given irradiation. The systematic uncertainty in the calibration of this beam monitor is estimated to be about 3%. The monitor reads out with a precision of 1 nA. The nominal current used in this work was about 30 nA, so this adds a second uncertainty of about 3%, for an overall uncertainty of about 4.5%.

A second method employing an aluminum activation foil (see Figure 2) was also used to determine the integrated proton fluence on the target assembly for each irradiation. The method employed a stack of three aluminum foils, each nominally 0.32 mm in thickness. The exact thickness of each foil was determined by weighing the foil and carefully measuring its dimensions (nominally 10 cm × 10 cm). Thicknesses measured with a

micrometer were also used to test the uniformity. Variations over the foil were found to be negligible. The proton beam fluence was then determined by counting the ^{24}Na activation products using a Germanium gamma-ray detector. Only the middle foil in each stack was counted, as the presence of the upstream and downstream foils was to ensure that the center foil was in equilibrium with any recoiling reaction products. The cross section for production of ^{24}Na by 800-MeV protons has been studied previously and has an uncertainty of less than 2% [11]. The half-life for ^{24}Na is 14.9590 hours, and the 1.368-MeV gamma ray is produced in 99.9936% of the decays. A calibrated ^{60}Co source was counted simultaneously with the aluminum foil. In this way the activity of the ^{24}Na could be determined by direct comparison of the counting rate with the ^{60}Co source, requiring only a small correction for the difference in energies between the 1.332-MeV gamma ray from ^{60}Co and the 1.368-MeV gamma ray from ^{24}Na . The ^{60}Co source was NIST-traceable, with quoted uncertainties of 2% (at the 99% confidence level). The measured activity was corrected for decay after irradiation. A small additional correction for decay of the ^{24}Na during the irradiation (2 to 4 hours) has been applied. Overall uncertainty in the proton beam determination by this method is less than 2%.

For the irradiation of the foil packets remaining on the target during the TOF measurements and receiving a much larger total proton fluence, a second aluminum foil was kept in the beam during the course of the second foil packet irradiation, and the setup and data runs for the TOF data. Since the duration of these irradiations was considerably longer than the half-life of ^{24}Na and occurred in a somewhat random sequence, the ^{22}Na activity was counted to determine the total proton fluence. The half-life for ^{22}Na decay is 2.602 years, and the 1.275-MeV gamma ray is produced in 99.98% of the decays. The ^{60}Co source was used in the same manner as for the ^{24}Na activity. Cross sections for production of ^{22}Na were also determined in Reference 11.

As indicated in Figure 2, a third device was also used to monitor the proton beam current. This was a Bergoz Model ICT-122-070-20:1 integrating current transformer (ICT). The transformer was mounted between the beamline vacuum exit window and the pellicle used in the beam imaging system. The signal was processed by a charge-sensitive preamplifier, linear main amplifier, and analog-to-digital converter (ADC). This device measured the charge in each micropulse of the beam and was used for real-time monitoring of the proton beam at the control station for the TOF experiments. Additionally the ADC outputs were stored in a histogram for each irradiation. The centroid of this histogram provided a measure of the average charge per beam pulse. Multiplication by the total number of beam pulses gave the integrated beam charge. This system was calibrated by recording the ADC output for the injection of a known charge into a wire loop through the ICT. Overall uncertainty of this technique was estimated to be 2%, determined mainly by the uncertainty of the injected calibration charge.

Table 6 summarizes the results for the determination of the total number of protons incident on the sample for each of the various irradiations. The values from the three methods were consistent within the estimated uncertainties. The values used to normalize the irradiations were taken to be the weighted average of the values from the three methods and have an uncertainty of less than 2%. Note that for the TOF measurements, only the facility current monitor and the ICT were used to determine total proton fluence.



Table 6. Determinations of Total Proton Fluence

Measurement	Facility	Uncertainty	Integrating	Uncertainty	Aluminum	Uncertainty	Weighted	Uncertainty	Uncertainty
	Monitor	(4.5-10%)	Current	(2%)	Activation	(2%)	Average	Absolute	%
Preliminary Results on Total Proton Fluences			Transformer						
Foil Irradiation (Primary foil activation measurement), AI No. 102	1.31E+16	5.9E+14	1.33E+16	2.7E+14	1.30E+16	2.6E+14	1.31E+16	1.8E+14	1.3
High Energy Neutron TOF, 40 cm target at position = 0 cm	1.51E+15	6.8E+13	1.57E+14	3.1E+12			1.60E+14	3.1E+12	2.0
High Energy Neutron TOF, 40 cm target at position = 20 cm	1.52E+15	6.8E+13	1.53E+15	3.1E+13			1.53E+15	2.8E+13	1.8
High Energy Neutron TOF, 40 cm target at position = 40 cm	1.77E+15	8.0E+13	1.78E+15	3.6E+13			1.78E+15	3.3E+13	1.8
Low Energy Neutron TOF, 40 cm target at position = 0 cm	3.45E+15	1.6E+14	3.42E+15	6.8E+13			3.42E+15	6.3E+13	1.8
Low Energy Neutron TOF, 40 cm target at position = 20 cm	2.94E+15	1.3E+14	2.96E+15	5.9E+13			2.96E+15	5.4E+13	1.8
Long Foil Irradiation (Foil packet for long-lived activation during primary irradiation plus TOF setup and data runs), AI No. 101	2.72E+16	1.2E+15			2.59E+16	5.2E+14	2.61E+16	4.8E+14	1.8
Low Energy Neutron TOF, 40 cm target at position = 40 cm	3.66E+15	1.6E+14	3.57E+15	7.1E+13			3.58E+15	6.6E+13	1.8
Low Energy Neutron TOF, 20 cm target at position = 0 cm	1.04E+15	1.0E+14	1.15E+15	2.3E+13			1.14E+15	2.2E+13	2.0
Low Energy Neutron TOF, 20 cm target at position = 20 cm	1.95E+15	2.0E+14	2.04E+15	4.1E+13			2.04E+15	4.0E+13	2.0
High Energy Neutron TOF, 20 cm target at position = 0 cm	7.00E+14	3.2E+13	7.18E+14	1.4E+13			7.15E+14	1.3E+13	1.8
High Energy Neutron TOF, 20 cm target at position = 20 cm	6.74E+14	3.0E+13	6.92E+14	1.4E+13			6.89E+14	1.3E+13	1.8
High Energy Neutron TOF, 20 cm target at position = 40 cm	6.83E+14	3.1E+13	6.81E+14	1.4E+13			6.81E+14	1.2E+13	1.8
AI No. 105 integrated over 20 cm diameter target TOF measurements	6.17E+15	4.9E+14			6.19E+15	1.2E+14	6.19E+15	1.2E+14	1.9



Neutron Leakage from a Lead-Bismuth Target
(Diameter = 40 cm, Length = 50 cm)

4.2 Foil Counting

The initial foil counting was performed in the LANSCE staging area according to the predetermined schedule. This schedule emphasized the counting of the Bi, Tb, and In foils first to get information on their short-lived isotopes, with counting then proceeding to the Au, Fe, Ni, Cu, and Co foils. The counting log in Appendix A lists the counts performed from July 9 through August 8, 2002. Some changes were made in the planned counting schedule as it progressed. For example, it was decided to count the In foils for shorter times (30 min vs. 45 min) because a shorter time provided adequate statistics and more subsequent counts could be made.

On July 11, after completion of the part of the TOF phase of the experiment, three foil packets (15, 20, and 22) that had been left on the target were withdrawn. Counting then began at the staging area on the materials in these packets. On July 16, a large number of the foils were packaged and shipped to C-INC (TA-48) for counting and recounting.

Building on work on the software and libraries for *PCGAP* from the previous experiment, more has been learned about the foils and reaction products, especially the Bi. More detailed analysis of the Bi has revealed strong overlap of the Bi-202 and Bi-202m gamma lines, making determination of these activities difficult. Additionally, more interferences have been found in the Bi-199 lines (Table 7). Previous analysis of the Bi foils showed higher-than-expected activities of Bi-199, and it now appears that interferences are responsible for this effect. The one detectable clean line of Bi-199 has a small branching ratio and is difficult to quantify (Figure 12).

Table 7. Bi-199 Gamma Lines and Interferences

Gamma Line (keV)	Intensity	Comment
411.80	82%	Also Tl-198(m)
425.30	22%	Also Tl-196(m)
841.70	11%	Very weak
1135.00	7.8%	Also Pb-199

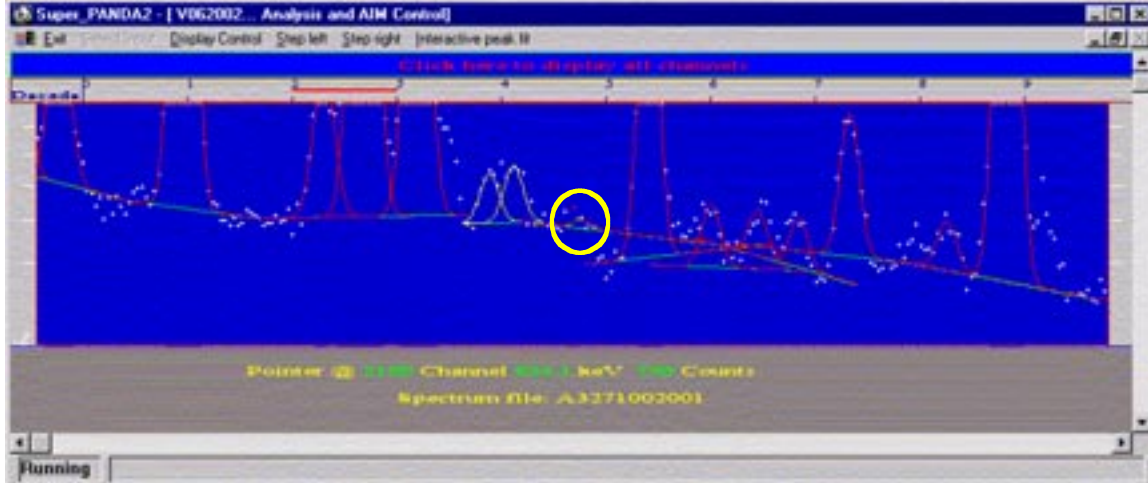


Figure 12. A portion of the Bi gamma spectrum. The center peak at 841.7 keV is the most prominent peak without interferences for Bi-199.

An analysis was performed on activities of Bi isotopes from foils around the target to analyze asymmetry in the neutron flux. The intensities of the gamma lines of three different energies were compared and the results are given in Figure 13. They show perhaps a slight shift in the center of the beam up and to the right.

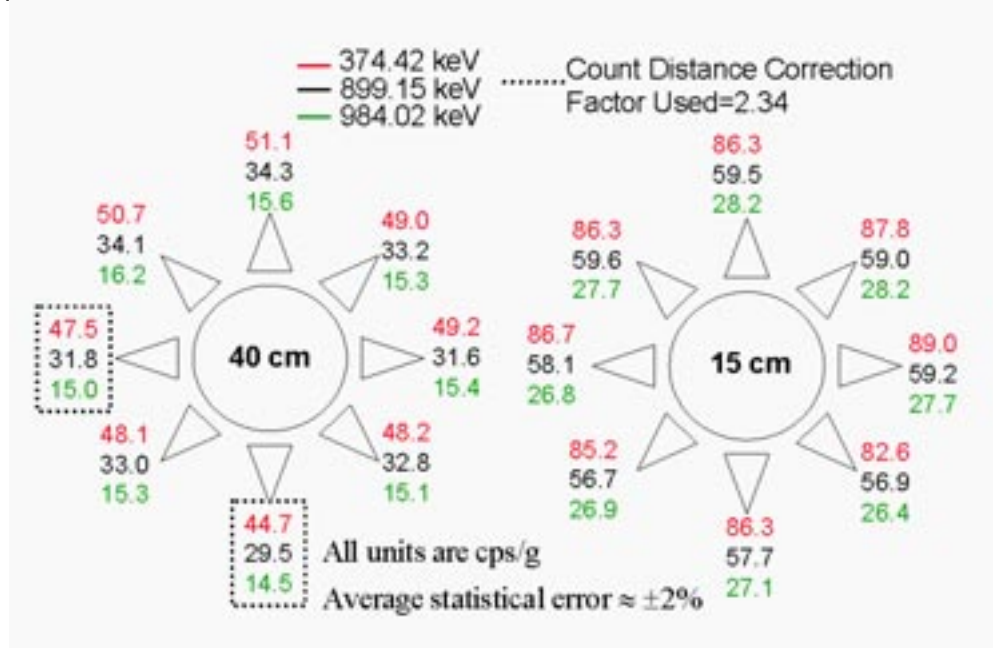


Figure 13. The activity of Bi-204 lines as a function of radial position at the 15-cm and 40-cm axial locations.

The activity of Bi along the length of the target was also computed. Those results are given in Figure 14, along with a comparison of an MCNPX run. It should be noted that the MCNPX calculation is summed over *all* neutron energies while the Bi-209 (n,6n)

reaction leading to Bi-204 has a threshold of 38.13 MeV; thus perfect agreement is not expected in the shape of the respective curves.

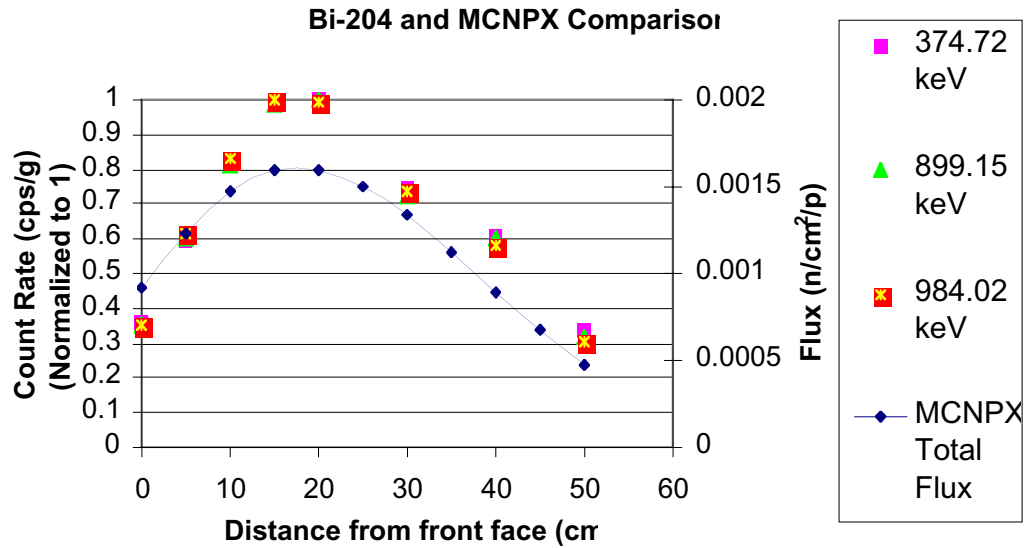


Figure 14. The ratio of activities for bismuth isotopes normalized to 1 at 15 cm.

Initial calculations have also been performed in MCNPX on the neutron spectra at various locations. This work will be used to compare the results of the activation foils and the TOF spectra. An example of the neutron spectra at the 15-cm axial location is given in Figure 15.

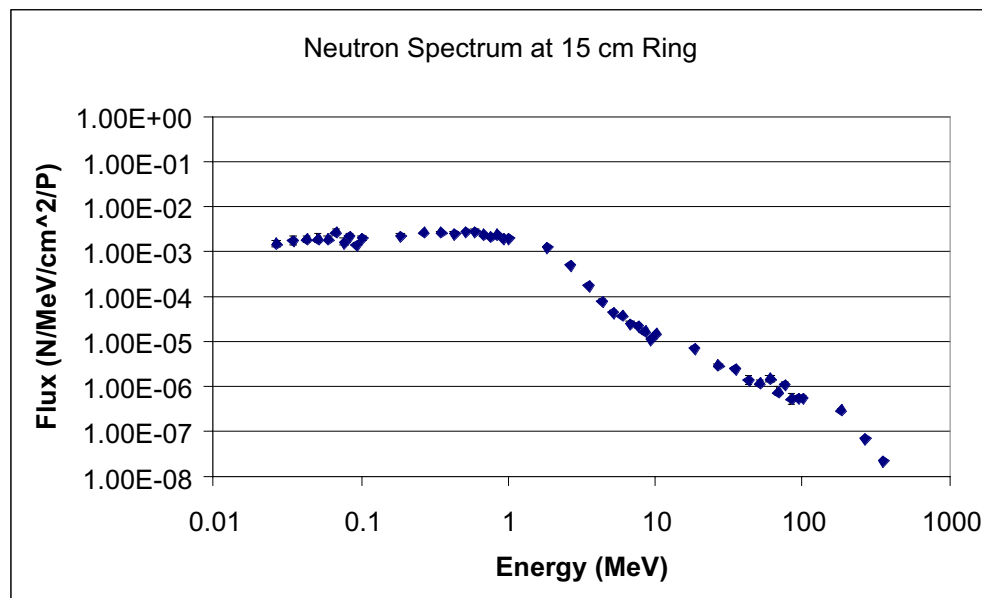


Figure 15. Neutron spectrum computed in MCNPX at the 15-cm axial location.

4.3 Nuclide Identification

Most of the irradiated foils present a very complex set of lines when presented to one of the High-Purity Germanium (HPGe) detectors. Since most of the work identifying lines and building libraries was accomplished as part of the last experiment, the work here focused on identifying the isotopes with the PCGAP package. Refer to the previous report [1] for more information on nuclide identification.

4.4 Time-of-Flight Measurements

Two data acquisition sequences were performed at each of the three target positions for each of the two targets employed. These target positions were nominally with the face of the target at 0 cm, 20 cm upstream, and 40 cm with respect to the intersection of the proton beam axis and flight path axes. However, in the series of experiments conducted with the 20-cm target, the target was inadvertently shifted 1 cm downstream so the target positions were actually -1, 19, and 39 cm. The first data acquisition sequence used the plastic detectors to obtain data in the high-neutron-energy region (~ 0.5 to 800°MeV). This required about 1.5 hours of beam (~ 20 nA) on target at each target position and used 20-microsecond spacing for the beam pulses. The second sequence used the Li-loaded glass detectors to obtain data in the lower-energy region (~ 0.01 to 1 MeV). About 8 hours of beam time (~ 25 nA) were required for each target position with a beam-pulse spacing of 40 microseconds.

An example of *preliminary* TOF spectra for the 40-cm target at 0 cm is shown in Figure°16. The data shown in this figure consist of neutron intensities as a function of neutron energy, normalized to unit incident proton. The data shown here are for detector distances of 51.15, 29.85, 59, and 30 m at angles of 7.5_i , 30_i , 60_i , and 150_i , respectively.

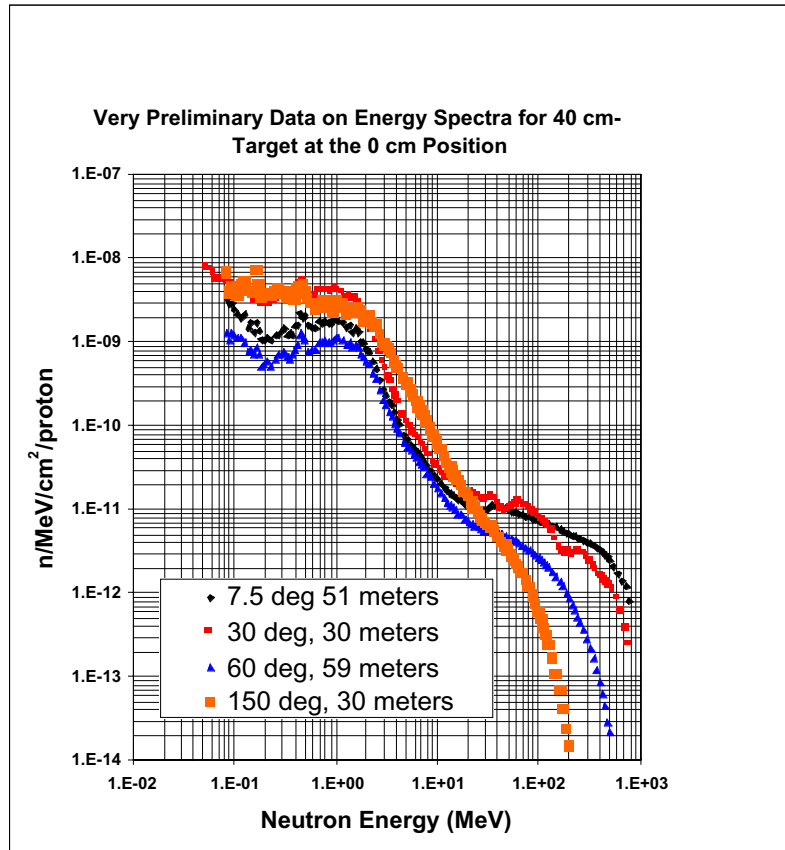


Figure 16. Time-of-flight spectra measured with the high-energy detectors for the target position at 0 cm. The data are for 7.5_i, 30_i, 60_i, and 150_i.

4.5 TA-48 Counting

After initial counting in the staging area, a large number of the foils were sent to TA-48 to be counted by the C-INC group. The foils shipped over were packets 16—19, 21, and 23—37 minus the Au foils, which were retained for further counting in the staging area. The foils were initially counted for 100 minutes each. Once the entire foil set was counted, further counts of 1000 minutes were begun for each foil. This period was reduced to 750 minutes on September 24 to reduce the overall time necessary to repeat all the foils. These counts are *not* included in the Count Log in Appendix A.

5. Summary

Follow-up experiments were conducted at the Target 2 facility (commonly called the Blue Room) at LANSCE to support the Advanced Accelerator Applications Program. These experiments were a continuation of irradiations conducted in December 2001. The current experiments consisted of irradiating a solid lead-bismuth target (diameter = 40 cm, length = 50 cm) with the 800-MeV proton beam and measuring the neutron emission from the target by two different methods activation foils and TOF measurements. In addition, a solid LBE target (diameter = 20 cm, length = 50 cm) that had been irradiated previously was used again to measure TOF data from two neutron flight path angles that had not been previously available.

Preliminary results indicate that both techniques for measuring the neutron leakage provide useful and complementary information. The activation foils provide significant quantities of integral reaction data that can be used for spectral unfolding, with errors representative of the uncertainties in the nuclear data. The TOF measurements provide very detailed information regarding the neutron spectra in a small solid angle (i.e., double differential data).

The goals of the target irradiation experiment were to:

1. add data from the larger, 40-cm target to the data gathered previously on the 20-cm target,
2. gather TOF data from the 60j and 150j beamlines from irradiation of the 20-cm target,
3. provide experimental data of benchmark quality to be used for validation of MCNPX,
4. provide experimenters with practical experience for conducting these types of measurements and data analysis activities, and
5. further develop methods and improve techniques for spectral unfolding using integral reaction data from activation foils.

While the data analysis is not yet complete, many of the goals of the irradiation experiment have been accomplished.

The initial irradiations provided data that were invaluable to the planning and conduct of the current irradiation campaign and analysis activities. The July 2002 irradiation was performed more efficiently and the quality of the data gathered was improved from the experience gained during the December irradiation.

Meticulous records of the experimental geometry and analysis of the data have been recorded. The records and results are of sufficient quality to include in a benchmark. The development of a benchmark report will begin in earnest.



Finally, the identification of peaks from target irradiations will serve to assist in the development and improvement of techniques for spectral unfolding. The identification of gamma peaks, as well as isotopes of interest from these initial irradiations, will allow a more thorough review of the production reactions and cross-section data. This review will allow a systematic approach to the improvement of the spectral unfolding process through the identification of deficiencies in dosimetry cross-section data, the unfolding process, and the identification of reaction data that provide similar results, i.e., the reactions can be used to check for consistency in counting results and flux determination, and the number of foils can be reduced in future irradiations thereby saving time and effort by eliminating redundant information requirements.

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Neutron Leakage from a Lead-Bismuth Target
(Diameter = 40 cm, Length = 50 cm)

Appendix A: Count Log

Stack #	Distance (cm)	Degrees	Foil #	Count File	Age (hr)	Distance (cm)	Start Date	Start Time	End Date	End Time	Real Time (s)	Live Time (s)	Dead Time (%)	Comments
Calibration			QCD98	A3370902000	N/A	10	9-Jul-02	5:40:00 PM	9-Jul-02	11:50:00 PM	22244.00	22211.00	0.15	
Background			N/A	A7171002000	N/A	N/A	10-Jul-02	12:23:00 AM	10-Jul-02	11:06:00 AM	38857.00	38317.00	1.39	QCD at Det 5 region
Background			N/A	A3171002000	N/A	N/A	10-Jul-02	12:24:00 AM	10-Jul-02	11:04:00 AM	38428.00	38419.00	0.02	QCD at Det 5 region
37	rear		8337	A3271002001	1.63	10	10-Jul-02	12:39:00 PM	10-Jul-02	1:26:22 PM	2819.64	2711.06	3.85	
21	40	0	8321	A7271002001	1.72	10.12	10-Jul-02	12:44:00 PM	10-Jul-02	1:32:37 PM	2933.26	2850.86	2.81	
19	20	0	8319	A3271002002	2.50	10	10-Jul-02	1:31:02 PM	10-Jul-02	2:16:56 PM	2754.45	2704.16	1.83	
18	15	0	8318	A7271002002	2.60	10.09	10-Jul-02	1:37:00 PM	10-Jul-02	2:23:55 PM	2815.14	2722.48	3.29	
17	10	0	8317	A3271002003	3.33	10	10-Jul-02	2:20:49 PM	10-Jul-02	3:05:00 PM	2700.94	2670.20	1.14	
16	5	0	8316	A7271002003	3.44	10	10-Jul-02	2:27:18 PM	10-Jul-02	3:12:24 PM	2705.08	2641.50	2.35	
35	40	270	8335	A3271002004	4.15	10	10-Jul-02	3:09:47 PM	10-Jul-02	4:09:55 PM	3608.26	3581.18	0.75	
33	40	180	8333	A7271002004	4.22	10	10-Jul-02	3:14:13 PM	10-Jul-02	4:04:39 PM	3007.78	2930.54	2.57	
31	40	90	8331	A7271002005	5.12	5	10-Jul-02	4:08:00 PM	10-Jul-02	4:54:29 PM	2774.94	2677.62	3.51	
28	15	270	8328	A3271002005	5.24	5	10-Jul-02	4:15:39 PM	10-Jul-02	5:02:05 PM	2799.30	2707.04	3.30	
26	15	180	8326	A7271002006	5.97	5.07	10-Jul-02	4:59:05 PM	10-Jul-02	5:46:42 PM	2861.22	2745.92	4.03	
24	15	90	8324	A3271002006	6.09	5	10-Jul-02	5:06:37 PM	10-Jul-02	5:51:31 PM	2701.04	2640.36	2.25	
Calibration			QCD98	A3371002000	N/A	5	10-Jul-02	5:50:06 PM	10-Jul-02	6:01:15 PM	669.18	656.06	1.96	
21	40	0	4921	A3271002007	6.91	5.042	10-Jul-02	5:55:43 PM	10-Jul-02	6:25:57 PM	1814.30	1801.80	0.69	
37	rear		4937	A7271002007	7.05	5	10-Jul-02	6:04:08 PM	10-Jul-02	6:30:45 PM	1600.20	1551.80	3.02	
19	20	0	4919	A3271002008	7.47	5	10-Jul-02	6:29:17 PM	10-Jul-02	6:59:50 PM	1832.38	1806.64	1.40	
18	15	0	4918	A7271002008	7.58	5	10-Jul-02	6:35:49 PM	10-Jul-02	7:05:51 PM	1801.50	1745.20	3.13	
17	10	0	4917	A3271002009	8.05	5	10-Jul-02	7:03:48 PM	10-Jul-02	7:33:52 PM	1803.94	1782.32	1.20	
16	5	0	4916	A7271002009	8.14	5.09	10-Jul-02	7:09:38 PM	10-Jul-02	7:48:14 PM	2311.48	2254.22	2.48	
16	5	0	6516	A3271002010	8.60	5	10-Jul-02	7:36:48 PM	10-Jul-02	8:16:49 PM	2399.72	2393.36	0.27	
17	10	0	6517	A7271002010	8.88	5	10-Jul-02	7:53:37 PM	10-Jul-02	8:24:04 PM	1826.58	1791.44	1.92	
18	15	0	6518	A3271002011	9.31	5	10-Jul-02	8:19:51 PM	10-Jul-02	8:50:19 PM	1815.62	1808.52	0.39	
19	20	0	6519	A7271002011	9.43	5	10-Jul-02	8:26:47 PM	10-Jul-02	8:56:48 PM	1801.08	1767.36	1.87	
21	40	0	6521	A3271002012	9.88	5	10-Jul-02	8:53:41 PM	10-Jul-02	9:23:43 PM	1801.60	1797.38	0.23	
33	40	180	4933	A3271002013	10.45	5	10-Jul-02	9:27:44 PM	10-Jul-02	9:58:00 PM	1814.34	1808.22	0.34	
31	40	90	4931	A7271002013	10.54	5	10-Jul-02	9:33:35 PM	10-Jul-02	10:03:36 PM	1802.24	1768.58	1.87	
28	15	270	4928	A3271002014	11.03	5	10-Jul-02	10:02:39 PM	10-Jul-02	10:24:06 PM	1887.96	1873.12	0.79	
26	15	180	4926	A7271002014	11.09	5	10-Jul-02	10:06:26 PM	10-Jul-02	10:42:58 PM	2191.38	2139.38	2.37	
24	15	90	4924	A3271002015	11.68	5	10-Jul-02	10:42:05 PM	10-Jul-02	11:12:27 PM	1813.66	1801.60	0.66	
25	15	135	4925	A7271002015	11.77	5	10-Jul-02	10:47:23 PM	10-Jul-02	11:17:49 PM	1827.10	1799.74	1.50	
23	15	45	4923	A3271002016	12.25	5	10-Jul-02	11:15:53 PM	10-Jul-02	11:46:05 PM	1811.56	1799.44	0.67	
27	15	225	4927	A7271002016	12.33	5	10-Jul-02	11:20:31 PM	10-Jul-02	11:51:07 PM	1836.56	1799.48	2.02	
30	40	45	4930	A3271002017	12.80	5	10-Jul-02	11:48:51 PM	11-Jul-02	12:19:02 AM	1805.12	1800.46	0.26	
32	40	135	4932	A7271002017	12.91	5.09	10-Jul-02	11:55:23 PM	11-Jul-02	12:25:32 AM	1832.30	1801.32	1.69	
34	40	225	4934	A3271102001	13.36	5	11-Jul-02	12:22:48 AM	11-Jul-02	12:53:02 AM	1805.66	1801.26	0.24	
36	40	315	4936	A7271102001	13.45	5.09	11-Jul-02	12:28:12 AM	11-Jul-02	12:58:42 AM	1830.24	1800.20	1.64	
29	15	315	4929	A3271102002	13.92	5	11-Jul-02	12:56:02 AM	11-Jul-02	1:26:20 AM	1825.84	1816.10	0.53	
37	rear		7941	A7271102002	14.00	5.09	11-Jul-02	1:01:11 AM	11-Jul-02	3:08:21 AM	7630.02	7199.92	5.64	
Calibration			QCD98	A3171102000	N/A	5	11-Jul-02	1:30:23 AM	11-Jul-02	1:42:18 AM	715.62	713.10	0.35	
21	40	0	7925	A3271102003	14.79	5	11-Jul-02	1:48:15 AM	11-Jul-02	3:58:20 AM	7799.88	7599.24	2.57	
19	20	0	7917	A3271102004	16.99	5	11-Jul-02	4:00:41 AM	11-Jul-02	5:15:41 AM	4500.24	4439.62	1.35	

Stack #	Distance (cm)	Degrees	Foil #	Count File	Age (hr)	Distance (cm)	Start Date	Start Time	End Date	End Time	Real Time (s)	Live Time (s)	Dead Time (%)	Comments
18	15	0	7914	A7271102003	17.00	5	11-Jul-02	4:01:16 AM	11-Jul-02	5:17:52 AM	4595.76	4476.82	2.59	
36	40	315	8336	A3271102005	18.27	5	11-Jul-02	5:16:58 AM	11-Jul-02	6:24:22 AM	4043.50	4005.40	0.94	
34	40	225	8334	A7271102004	18.31	5	11-Jul-02	5:19:23 AM	11-Jul-02	6:20:02 AM	3638.24	3562.42	2.08	
32	40	135	8332	A7271102005	19.37	5	11-Jul-02	6:23:17 AM	11-Jul-02	7:23:19 AM	3601.26	3531.76	1.93	
30	40	45	8330	A3271102006	19.42	5	11-Jul-02	6:26:17 AM	11-Jul-02	7:26:25 AM	3606.74	3574.02	0.91	
29	15	315	8329	A7271102006	20.39	5.09	11-Jul-02	7:24:15 AM	11-Jul-02	8:24:13 AM	3582.84	3531.48	1.43	
27	15	225	8327	A3271102007	20.44	5	11-Jul-02	7:27:40 AM	11-Jul-02	8:27:41 AM	3600.64	3550.68	1.39	
25	15	135	8325	A7271102007	21.52	5	11-Jul-02	8:32:13 AM	11-Jul-02	9:34:13 AM	3750.38	3688.26	1.66	
23	15	45	8323	A3271102008	21.53	5	11-Jul-02	8:32:31 AM	11-Jul-02	9:32:13 AM	3638.62	3592.86	1.26	
35	40	270	7939	A3271102009	22.61	5	11-Jul-02	9:37:18 AM	11-Jul-02	10:44:28 AM	4030.10	3944.90	2.11	
17	10	0	7912	A7271102008	22.63	5	11-Jul-02	9:38:50 AM	11-Jul-02	10:47:34 AM	4123.90	4062.50	1.49	
16	5	0	7906	A3271102010	23.77	5	11-Jul-02	10:46:56 AM	11-Jul-02	12:06:07 PM	4751.26	4696.28	1.16	
33	40	180	7937	A7271102009	23.85	5	11-Jul-02	10:52:17 AM	11-Jul-02	12:11:49 PM	4768.80	4660.54	2.27	
Calibration			QCD98	A3371102000	N/A	5	11-Jul-02	12:10:49 PM	11-Jul-02	12:40:00 PM	1816.08	1809.76	0.35	
31	40	90	7935	A7271102010	25.25	5.065	11-Jul-02	12:15:58 PM	11-Jul-02	1:32:46 PM	4607.56	4492.10	2.51	
28	15	270	7932	A3271102011	25.76	5	11-Jul-02	12:46:39 PM	11-Jul-02	2:17:47 PM	5555.42	5383.82	3.09	
26	15	180	7930	A7271102011	26.62	5	11-Jul-02	1:38:14 PM	11-Jul-02	2:39:14 PM	3613.86	3484.04	3.59	
24	15	90	7928	A3271102012	27.33	5	11-Jul-02	2:20:52 PM	11-Jul-02	3:05:55 PM	2700.54	1625.50	39.81	
36	40	315	7940	A7271102012	27.70	5	11-Jul-02	2:42:52 PM	11-Jul-02	3:27:52 PM	2700.54	2631.08	2.57	
34	40	225	7938	A3271102013	28.12	5	11-Jul-02	3:07:55 PM	11-Jul-02	3:52:56 PM	2700.26	2649.40	1.88	
27	15	225	7931	A7271102013	28.54	5	11-Jul-02	3:33:28 PM	11-Jul-02	4:19:19 PM	2750.94	2648.92	3.71	
32	40	135	7936	A3271102014	28.91	5	11-Jul-02	3:55:30 PM	11-Jul-02	4:40:45 PM	2715.20	2666.86	1.78	
30	40	45	7934	A7271102014	29.34	5	11-Jul-02	4:21:11 PM	11-Jul-02	5:07:51 PM	2799.62	2709.44	3.22	
29	15	315	7933	A3271102015	29.70	5	11-Jul-02	4:42:58 PM	11-Jul-02	5:54:07 PM	4268.14	4137.10	3.07	
25	15	135	7929	A7271102015	30.19	5	11-Jul-02	5:12:34 PM	11-Jul-02	6:17:15 PM	3880.62	3728.76	3.91	
22	50	0	8322	A7471102001	0.91	10	11-Jul-02	6:24:26 PM	11-Jul-02	6:53:37 PM	1886.04	1812.96	3.87	
15	0	0	8315	A3471102001	0.93	10	11-Jul-02	6:25:38 PM	11-Jul-02	6:58:44 PM	2097.92	2084.90	0.62	
20	30	0	8320	A7471102002	1.46	10	11-Jul-02	6:57:43 PM	11-Jul-02	7:28:43 PM	1859.90	1808.90	2.74	
22	50	0	6522	A3471102002	1.54	5	11-Jul-02	7:02:35 PM	11-Jul-02	7:40:18 PM	2245.50	2239.84	0.25	
15	0	0	6515	A7471102003	2.03	5	11-Jul-02	7:31:35 PM	11-Jul-02	8:12:59 PM	2492.00	2410.66	3.26	
20	30	0	6520	A3471102003	2.20	5	11-Jul-02	7:42:10 PM	11-Jul-02	8:16:12 PM	2041.68	2030.04	0.57	
22	50	0	4922	A7471102004	2.75	5	11-Jul-02	8:15:16 PM	11-Jul-02	8:50:56 PM	2139.90	2047.52	4.32	
15	0	0	4915	A3471102004	2.82	5	11-Jul-02	8:19:04 PM	11-Jul-02	8:56:37 PM	2252.88	2202.94	2.22	
20	30	0	4920	A7471102005	3.41	5.07	11-Jul-02	8:54:48 PM	11-Jul-02	9:29:23 PM	2074.58	1960.20	5.51	
22	50	0	7926	A3471102005	3.48	5	11-Jul-02	8:58:57 PM	11-Jul-02	10:00:00 PM	3662.88	3520.76	3.88	
35	40	270	4935	A7271002012	33.98	5	11-Jul-02	9:00:00 PM	10-Jul-02	9:30:35 PM	1833.18	1799.24	1.85	
15	0	0	7905	A7471102006	4.05	5	11-Jul-02	9:33:08 PM	11-Jul-02	10:35:44 PM	3756.30	3560.12	5.22	
20	30	0	7921	A3471102006	4.57	5	11-Jul-02	10:04:15 PM	11-Jul-02	11:05:36 PM	3681.64	3591.24	2.46	
Calibration			QCD98	A7371102000	N/A	5.05	11-Jul-02	10:39:00 PM	11-Jul-02	11:09:52 PM	1865.22	1800.20	3.49	
23	15	45	7927	A3271202000	36.12	5	11-Jul-02	11:08:13 PM	12-Jul-02	8:22:19 AM	33064.84	32189.28	2.65	
37	rear		8337	A7271202000	36.22	5	11-Jul-02	11:14:15 PM	12-Jul-02	8:20:10 AM	32711.34	31325.38	4.24	
21	40	0	8321	A3271202001	46.40	5	12-Jul-02	9:25:01 AM	12-Jul-02	11:30:04 AM	7502.92	7473.08	0.40	
19	20	0	8319	A7271202001	46.41	5	12-Jul-02	9:25:44 AM	12-Jul-02	11:36:46 AM	7635.06	7403.96	3.03	
18	15	0	8318	A7271202002	48.72	5	12-Jul-02	11:44:10 AM	12-Jul-02	1:56:21 PM	7950.80	7660.66	3.65	

Stack #	Distance (cm)	Degrees	Foil #	Count File	Age (hr)	Distance (cm)	Start Date	Start Time	End Date	End Time	Real Time (s)	Live Time (s)	Dead Time (%)	Comments
17	10	0	8317	A3271202002	48.73	5	12-Jul-02	11:44:46 AM	12-Jul-02	1:54:46 PM	7830.14	7786.64	0.56	
16	5	0	8316	A3271202003	51.04	5	12-Jul-02	2:03:40 PM	12-Jul-02	4:11:17 PM	7656.68	7626.28	0.40	
22	50	0	8322	A7271202003	20.64	5	12-Jul-02	2:08:28 PM	12-Jul-02	4:13:35 PM	7505.64	7329.06	2.35	
15	0	0	8315	A7271202004	22.81	5	12-Jul-02	4:18:44 PM	12-Jul-02	7:32:17 PM	11611.74	11147.24	4.00	
20	30	0	8320	A3271202004	22.83	5	12-Jul-02	4:19:41 PM	12-Jul-02	7:28:42 PM	11339.88	11181.16	1.40	
17	10	0	6517	A7271202005	56.89	5	12-Jul-02	7:54:11 PM	12-Jul-02	10:26:22 PM	9128.88	9011.06	1.29	
16	5	0	6516	A3271202005	56.94	5	12-Jul-02	7:57:24 PM	12-Jul-02	10:20:55 PM	8611.10	8596.60	0.17	
18	15	0	6518	A3271302001	59.41	5	12-Jul-02	10:25:38 PM	13-Jul-02	9:46:16 AM	40836.00	40744.00	0.23	
19	20	0	6519	A7271302001	59.48	5	12-Jul-02	10:30:00 PM	13-Jul-02	9:37:09 AM	40027.00	39168.00	2.15	
Calibration			QCD98	A7171302000	N/A	5.035	13-Jul-02	9:43:39 AM	13-Jul-02	10:14:46 AM	1866.90	1849.26	0.94	
20	30	0	6520	A3271302002	40.37	5	13-Jul-02	9:52:25 AM	13-Jul-02	11:20:02 AM	12456.40	12410.52	0.37	
21	40	0	6521	A7271302002	71.39	5	13-Jul-02	10:24:13 AM	13-Jul-02	1:47:29 PM	12194.84	12037.64	1.29	
Calibration			QCD98	A7271302002	N/A	5	13-Jul-02	1:35:30 PM	13-Jul-02	2:06:00 PM	1892.57	1886.20	0.34	
15	0	0	6515	A7271302003	44.39	5.085	13-Jul-02	1:53:15 PM	13-Jul-02	5:11:00 PM	11921.06	11811.90	0.92	
22	50	0	6522	A3271302003	44.72	5	13-Jul-02	2:13:00 PM	13-Jul-02	5:16:31 PM	10965.94	10948.62	0.16	
51	15	0	7950	A7271402001		5	13-Jul-02	5:15:00 PM	14-Jul-02	9:10:00 AM	57332.42	55953.12	2.41	
51	15	0	7951	A3271402001		5	13-Jul-02	5:19:47 PM	14-Jul-02	9:05:00 AM	56774.28	56473.22	0.53	
51	15	0	7952	A3271402002		5	14-Jul-02	9:09:00 AM	14-Jul-02	11:18:49 AM	7741.30	7704.92	0.47	
52	rear		7955	A7271402002		5	14-Jul-02	9:13:00 AM	14-Jul-02	11:20:43 AM	7632.68	7511.60	1.59	
52	rear		7956	A3271402003		5	14-Jul-02	11:24:08 AM	14-Jul-02	12:39:15 PM	4507.96	4487.72	0.45	
52	rear		7957	A7271402003		5	14-Jul-02	11:26:31 AM	14-Jul-02	12:52:00 PM	5128.96	4924.92	3.98	
15	0	0	1315	A3271402004	67.22	5	14-Jul-02	12:43:09 PM	14-Jul-02	3:37:19 PM	10449.86	10447.14	0.03	
20	30	0	1320	A7271402004	67.41	5	14-Jul-02	12:54:52 PM	14-Jul-02	3:42:35 PM	10000.00	9645.08	3.55	
15	0	0	2615	A3271402005	70.20	5	14-Jul-02	3:41:58 PM	14-Jul-02	6:01:00 PM	8351.94	8349.36	0.03	
20	30	0	2620	A7271402005	70.27	5	14-Jul-02	3:46:22 PM	14-Jul-02	6:42:45 PM	10475.00	10106.00	3.52	
22	50	0	2622	A7271502001	73.64	5	14-Jul-02	7:08:28 PM	15-Jul-02	8:42:00 AM	48854.00	47254.00	3.28	
22	50	0	1322	A3271502001	73.84	5	14-Jul-02	7:20:24 PM	15-Jul-02	8:47:00 AM	48400.00	48388.00	0.02	
15	0	0	2715	A7271502002	87.25	5	15-Jul-02	8:45:00 AM	15-Jul-02	12:06:00 PM	12013.00	11633.00	3.16	
20	30	0	2720	A3271502002	87.33	5	15-Jul-02	8:49:32 AM	15-Jul-02	12:01:00 PM	11516.00	11509.00	0.06	
15	0	0	4915	A3271502003	90.57	5	15-Jul-02	12:04:00 PM	15-Jul-02	4:18:50 PM	15235.00	15228.00	0.05	
22	50	0	4922	A7271502003	90.65	5	15-Jul-02	12:09:00 PM	15-Jul-02	4:14:26 PM	14692.62	14193.98	3.39	
20	30	0	4920	A7271502004	94.79	5	15-Jul-02	4:17:35 PM	15-Jul-02	7:25:00 PM	11266.00	10884.00	3.39	
22	50	0	2722	A3271502004	94.86	5	15-Jul-02	4:21:38 PM	15-Jul-02	7:28:28 PM	11022.00	11017.00	0.05	
Background			N/A	A3171602000	N/A	N/A	15-Jul-02	7:31:00 PM	16-Jul-02	8:16:58 AM	45915.54	45905.24	0.02	QCD at Det 5 region
Background			N/A	A7171602000	N/A	N/A	15-Jul-02	7:32:00 PM	16-Jul-02	8:21:41 AM	46136.48	44752.42	3.00	QCD at Det 5 region
15	0	0	7905	A3271702000	109.21	5	16-Jul-02	6:42:25 AM	17-Jul-02	8:05:32 AM	48185.64	47929.42	0.53	
15	0	0	2815	A3271602000	111.00	5	16-Jul-02	8:30:15 AM	16-Jul-02	11:13:55 AM	9819.68	9810.48	0.09	
20	30	0	2820	A7271602000	111.01	5	16-Jul-02	8:30:50 AM	16-Jul-02	12:07:52 PM	13021.40	12851.46	1.31	
Calibration			QCD98	A3171602001	N/A	5.02	16-Jul-02	11:17:26 AM	16-Jul-02	12:05:05 PM	2858.72	2848.76	0.35	
Calibration			QCD98	A7171602001	N/A	5.045	16-Jul-02	12:12:27 PM	16-Jul-02	1:39:52 PM	5244.00	5185.00	1.13	
22	50	0	2822	A3271602001	114.73	5	16-Jul-02	12:13:41 PM	16-Jul-02	3:15:02 PM	10880.60	10875.22	0.05	
15	0	0	2915	A7271602001	116.32	5	16-Jul-02	1:49:00 PM	16-Jul-02	6:33:00 PM	16998.00	16442.00	3.27	
20	30	0	2920	A3271602002	117.86	5	16-Jul-02	3:21:49 PM	16-Jul-02	6:39:16 PM	11846.00	11842.00	0.03	
22	50	0	2922	A7271702000	121.13	5	16-Jul-02	6:38:00 PM	17-Jul-02	8:03:38 AM	48319.22	47591.94	1.51	
20	30	0	7921	A3271702001	134.68	5	17-Jul-02	8:10:51 AM	17-Jul-02	12:05:00 PM	14107.00	14024.00	0.59	

Stack #	Distance (cm)	Degrees	Foil #	Count File	Age (hr)	Distance (cm)	Start Date	Start Time	End Date	End Time	Real Time (s)	Live Time (s)	Dead Time (%)	Comments
22	50	0	7926	A7271702001	134.69	5	17-Jul-02	8:11:27 AM	17-Jul-02	12:18:38 PM	14890.00	14477.00	2.77	
21	40	0	7925	A3271702002	169.16	5	17-Jul-02	12:10:21 PM	17-Jul-02	3:42:00 PM	12342.00	12281.00	0.49	
37	rear		7941	A7271702002	169.39	5	17-Jul-02	12:24:22 PM	17-Jul-02	3:49:15 PM	12325.00	12162.00	1.32	
19	20	0	7917	A3271702003	172.80	5	17-Jul-02	3:48:53 PM	17-Jul-02	7:47:49 PM	14335.00	14297.00	0.27	
18	15	0	7914	A7271702003	172.89	5	17-Jul-02	3:54:15 PM	17-Jul-02	7:52:47 PM	14310.00	13793.00	3.61	
35	40	270	7939	A3271802000	176.84	5	17-Jul-02	7:51:41 PM	18-Jul-02	8:30:28 AM	45925.96	45343.62	1.27	
17	10	0	7912	A7271802000	176.99	5	17-Jul-02	8:00:07 PM	18-Jul-02	8:27:41 AM	44851.70	43290.70	3.48	
16	5	0	7906	A3271802001	189.58	5	18-Jul-02	8:35:36 AM	18-Jul-02	11:55:00 AM	11980.00	11954.00	0.22	
33	40	180	7937	A7271802001	189.59	5	18-Jul-02	8:36:11 AM	18-Jul-02	11:49:18 AM	11585.00	11248.00	2.91	
31	40	90	7935	A7271802002	192.88	5	18-Jul-02	11:54:00 AM	18-Jul-02	4:30:54 PM	16601.00	16310.00	1.75	
28	15	270	7932	A3271802002	192.95	5	18-Jul-02	11:58:00 AM	18-Jul-02	4:26:00 PM	16076.00	15986.00	0.56	
24	15	90	7928	A3271802003	197.48	5	18-Jul-02	4:30:00 PM	18-Jul-02	7:13:09 AM	9771.00	9716.00	0.56	
26	15	180	7930	A7271802003	197.55	5	18-Jul-02	4:34:00 PM	18-Jul-02	7:17:47 PM	9774.00	9408.00	3.74	
34	40	225	7938	A3271902000	200.27	5	18-Jul-02	7:16:58 PM	19-Jul-02	7:45:04 AM	44884.66	44745.96	0.31	
36	40	315	7940	A7271902000	200.33	5	18-Jul-02	7:20:39 PM	19-Jul-02	7:49:47 AM	44944.00	43467.72	3.28	
32	40	135	7936	A3271902001	212.80	5	19-Jul-02	7:48:57 AM	19-Jul-02	11:51:00 AM	14552.00	14512.00	0.27	
27	15	225	7931	A7271902001	212.84	5	19-Jul-02	7:51:38 AM	19-Jul-02	11:58:59 AM	14839.00	14655.00	1.24	
Calibration			QCD98	A3171902000	N/A	5.015	19-Jul-02	11:57:00 AM	19-Jul-02	12:30:00 PM	1982.06	1975.16	0.35	
30	40	45	7934	A7271902002	217.02	5	19-Jul-02	12:02:04 PM	19-Jul-02	3:25:40 AM	12215.00	11828.00	3.17	
29	15	315	7933	A3271902002	217.53	5	19-Jul-02	12:33:00 PM	19-Jul-02	3:51:43 PM	11911.00	11856.00	0.46	
Calibration			QCD98	A7171902000	N/A	5.055	19-Jul-02	3:30:41 PM	19-Jul-02	4:00:00 PM	1808.46	1757.14	2.84	
23	15	45	7927	A3271902003	220.90	5	19-Jul-02	3:55:17 PM	19-Jul-02	7:24:35 PM	12556.00	12501.00	0.44	
25	15	135	7929	A7271902003	221.05	5	19-Jul-02	4:04:01 PM	19-Jul-02	7:29:23 PM	12321.00	11931.00	3.17	
22	50	0	6522	A3272002001	193.97	5	19-Jul-02	7:28:00 PM	20-Jul-02	8:38:54 AM	47418.00	47365.00	0.11	
15	0	0	6515	A7272002001	194.04	5	19-Jul-02	7:32:32 PM	20-Jul-02	8:34:38 AM	46924.00	45441.00	3.16	
22	50	0	4922	A7272002002	207.14	5	20-Jul-02	8:38:34 AM	20-Jul-02	3:00:00 PM	22885.00	22484.00	1.75	
20	30	0	6520	A3272002002	207.19	5	20-Jul-02	8:41:30 AM	20-Jul-02	3:05:13 PM	23021.00	22963.00	0.25	
20	30	0	4920	A7272002003	213.57	5	20-Jul-02	3:04:00 PM	20-Jul-02	9:02:33 PM	21440.00	20788.00	3.04	
15	0	0	4915	A3272002003	213.64	5	20-Jul-02	3:08:20 PM	20-Jul-02	9:06:27 PM	21486.00	21479.00	0.03	
22	50	0	8322	A7272102000	219.59	5	20-Jul-02	9:05:33 PM	21-Jul-02	10:21:22 AM	47807.28	47367.76	0.92	
15	0	0	8315	A3272102000	219.66	5	20-Jul-02	9:09:21 PM	21-Jul-02	10:17:38 AM	47356.86	47278.00	0.17	
15	0	0	2615	A3272102001	232.84	5	21-Jul-02	10:20:18 AM	21-Jul-02	11:11:00 PM	46277.00	46264.00	0.03	
20	30	0	8320	A7272102001	232.89	5	21-Jul-02	10:23:34 AM	21-Jul-02	11:24:02 PM	46825.00	46385.00	0.94	
20	30	0	2720	A3272202000	245.87	5	21-Jul-02	11:22:00 PM	22-Jul-02	8:16:22 AM	32023.90	32006.10	0.06	
20	30	0	2620	A7272202000	245.95	5	21-Jul-02	11:27:00 PM	22-Jul-02	8:14:26 AM	31600.16	31345.58	0.81	
22	50	0	2622	A7272202001	256.86	5	22-Jul-02	10:21:19 AM	22-Jul-02	4:48:20 AM	23219.00	23078.00	0.61	
15	0	0	2715	A7272302000	263.36	5	22-Jul-02	4:51:19 PM	23-Jul-03	7:26:24 AM	52502.68	52177.66	0.62	
22	50	0	2722	A3272302000	263.39	5	22-Jul-02	4:53:39 PM	23-Jul-02	7:24:14 AM	52232.62	52213.68	0.04	
15	0	0	2815	A3272302001	277.99	5	23-Jul-02	7:29:17 AM	23-Jul-02	1:39:44 PM	22226.00	22208.00	0.08	Wide pulse shape - recounted
20	30	0	2820	A7272302001	278.02	5	23-Jul-02	7:31:21 AM	23-Jul-02	1:35:10 PM	21827.00	21675.00	0.70	
15	0	0	2915	A7272302002	284.16	5	23-Jul-02	1:39:20 PM	23-Jul-02	6:57:39 PM	19098.00	18976.00	0.64	
22	50	0	2822	A3272302002	284.16	5	23-Jul-02	1:39:44 PM	23-Jul-02	7:02:19 PM	19178.00	19170.00	0.04	
20	30	0	2920	A3272402001	291.16	5	23-Jul-02	8:39:20 PM	24-Jul-02	9:29:54 AM	46231.00	46219.00	0.03	
22	50	0	2922	A7272402001	291.17	5	23-Jul-02	8:40:03 PM	24-Jul-02	9:22:44 AM	45819.00	45530.00	0.63	

Stack #	Distance (cm)	Degrees	Foil #	Count File	Age (hr)	Distance (cm)	Start Date	Start Time	End Date	End Time	Real Time (s)	Live Time (s)	Dead Time (%)	Comments
15	0	0	7905	A7272402002	303.98	5	24-Jul-02	9:29:00 AM	24-Jul-02	2:10:55 PM	16914.00	16744.00	1.01	
20	30	0	7921	A7272402003	308.72	5	24-Jul-02	2:13:06 PM	24-Jul-02	7:45:13 PM	19925.00	19705.00	1.10	
22	50	0	7926	A3272502000	314.25	5	24-Jul-02	7:45:13 PM	25-Jul-02	8:30:10 AM	45976.24	45898.68	0.17	
15	0	0	2815	A7272502000	314.34	5	24-Jul-02	7:50:13 PM	26-Jul-02	8:32:20 AM	45724.74	45334.18	0.85	recount
22	50	0	2722	A7272502001	327.11	5	25-Jul-02	8:36:24 AM	25-Jul-02	2:12:12 PM	20194.00	20017.00	0.88	
22	50	0	2822	A3272502001	327.12	5	25-Jul-02	8:37:14 AM	25-Jul-02	2:08:17 PM	19862.00	19854.00	0.04	
20	30	0	2920	A7272502002	332.83	5	25-Jul-02	2:19:39 PM	25-Jul-02	7:38:43 PM	19142.00	18966.00	0.92	
Calibration			QCD98	A3272502002	N/A	5.005	25-Jul-02	6:20:00 PM	25-Jul-02	6:54:34 AM	2059.50	2052.30	0.35	
15	0	0	8315	A7272602001	338.22	5	25-Jul-02	7:43:04 PM	26-Jul-02	12:31:52 PM	60524.00	60472.00	0.09	
Background			N/A	A3172602000	N/A	N/A	25-Jul-02	7:54:13 PM	26-Jul-02	12:42:00 PM	60487.00	60472.00	0.02	
Calibration			QCD98	A7172602000	N/A	5.05	26-Jul-02	12:40:05 PM	26-Jul-02	3:55:52 PM	11746.00	11598.00	1.26	
22	50	0	6522	A3272602001	355.32	5	26-Jul-02	12:49:18 PM	26-Jul-02	6:44:50 PM	21331.00	21310.00	0.10	
22	50	0	8322	A7272902001	361.12	5	26-Jul-02	6:37:23 PM	29-Jul-02	9:22:00 AM	225875.00	223702.00	0.96	
15	0	0	1315	A3272902001	361.34	5	26-Jul-02	6:50:09 PM	29-Jul-02	9:34:08 AM	225830.00	225774.00	0.02	
20	30	0	8320	A7272902002	424.78	5	29-Jul-02	10:16:30 AM	29-Jul-02	7:43:59 PM	34048.00	33840.00	0.61	
15	0	0	6515	A7273002001	434.31	5	29-Jul-02	7:48:52 PM	30-Jul-02	4:48:08 PM	75552.00	75022.00	0.70	
20	30	0	6520	A3273002001	434.38	5	29-Jul-02	7:53:00 PM	30-Jul-02	1:13:56 PM	62426.00	62300.00	0.20	
15	0	0	4915	A3273102001	451.86	5	30-Jul-02	1:21:47 PM	31-Jul-02	6:08:00 PM	103569.00	103530.00	0.04	
22	50	0	4922	A7273102001	455.42	5	30-Jul-02	4:55:20 PM	31-Jul-02	6:16:18 PM	91254.00	90716.00	0.59	
22	50	0	7926	A3280102001	480.75	5	31-Jul-02	6:14:51 PM	1-Aug-02	4:35:49 PM	80454.00	79946.00	0.63	
15	0	0	7905	A7280102001	2284.28	5	31-Jul-02	9:47:00 PM	1-Aug-02	4:26:08 PM	79458.00	79191.00	0.34	
20	30	0	4920	A7280202001	503.08	5	1-Aug-02	4:34:42 PM	2-Aug-02	7:21:42 PM	96476.00	95843.00	0.66	
20	30	0	7921	A3280202001	503.20	5	1-Aug-02	4:41:46 PM	2-Aug-02	7:14:51 PM	95642.00	95438.00	0.21	
15	0	0	2615	A3280302001	529.84	5	2-Aug-02	7:20:19 PM	3-Aug-02	12:18:24 PM	61083.00	61067.00	0.03	
20	30	0	2620	A7280302001	529.94	5	2-Aug-02	7:26:15 PM	3-Aug-02	12:27:35 PM	61276.00	60883.00	0.64	
20	30	0	2720	A3280402001	546.93	5	3-Aug-02	12:26:03 PM	4-Aug-02	5:46:02 PM	105625.00	105570.00	0.05	
22	50	0	2622	A7280402001	547.03	5	3-Aug-02	12:32:03 PM	4-Aug-02	5:40:00 PM	104873.00	104209.00	0.63	
15	0	0	2715	A7280502001	576.25	5	4-Aug-02	5:45:08 PM	5-Aug-02	5:53:26 PM	86894.00	86315.00	0.67	
22	50	0	2722	A3280502001	576.36	5	4-Aug-02	5:51:33 PM	5-Aug-02	6:03:40 PM	87123.00	87093.00	0.03	
20	30	0	2820	A7280602001	602.18	5	5-Aug-02	7:40:42 PM	6-Aug-02	11:30:19 AM	56943.00	56575.00	0.65	
Calibration			QCD98	A3180602000	N/A	5	6-Aug-02	9:01:00 AM	6-Aug-02	11:14:53 AM	8021.00	7993.00	0.35	
Calibration			QCD98	A3180602001	N/A	5	6-Aug-02	6:14:00 PM	6-Aug-02	7:02:00 PM	2900.00	2890.00	0.34	
20	30	0	2820	A7280702001	624.88	5	6-Aug-02	6:22:31 PM	7-Aug-02	11:14:00 AM	60692.00	60336.00	0.59	immediate recount B-1 magnets moved
15	0	0	2815	A3280702001	625.62	5	6-Aug-02	7:07:00 PM	7-Aug-02	11:19:36 AM	58339.00	58297.00	0.07	
15	0	0	2815	A7280802001	650.33	5	7-Aug-02	7:49:51 PM	8-Aug-02	2:01:00 PM	65485.00	65085.00	0.61	
22	50	0	2822	A3280802001	650.40	5	7-Aug-02	7:54:08 PM	8-Aug-02	10:32:25 AM	52695.00	52674.00	0.04	
Calibration			63752-16	A7180802000	N/A	4.99	8-Aug-02	2:18:56 PM	8-Aug-02	3:40:25 PM	4891.10	4786.24	2.14	
Calibration			63752-16	A7180802001	N/A	9.99	8-Aug-02	3:46:00 PM	8-Aug-02	6:22:00 PM	9409.00	9295.00	1.21	
Calibration			63752-16	A3180802000	N/A	4.94	8-Aug-02	6:28:15 PM	8-Aug-02	7:22:00 PM	3257.00	3212.00	1.38	
Calibration			63752-16	A3180802001	N/A	9.95	8-Aug-02	7:26:00 PM	8-Aug-02	8:53:00 PM	5195.00	5167.00	0.54	
Background			N/A	A7180902000	N/A	N/A	8-Aug-02	9:04:00 PM	9-Aug-02	4:32:41 PM	70104.00	69172.00	1.33	
Background			N/A	A3180902000	N/A	N/A	8-Aug-02	9:04:00 PM	9-Aug-02	4:39:56 PM	70570.00	70553.00	0.02	